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GENETIC DIVERGENCE STUDIES OF CROSSES DEVELOPED THROUGH NORTH CAROLINA DESIGN-I, II AND III IN COTTON (*GOSSYPIUM HIRSUTUM* L.)

A. P. Chaudhary[1*], Y.A. Garde[1], B. A. Chaudhari[2], P. B. Patel[3], Alok Shrivastava[1], Nitin Varshney[1] and Vishal Thorat[4]

[1]Department of Agricultural Statistics, N. M. College of Agriculture
Navsari Agricultural University (NAU), Navsari, Gujarat, India
[2]Agricultural Research Station, NAU, Achhalia, Gujarat, India
[3]Main Rice Research Station, NAU, Navsari, Gujarat, India
[4]ASPEE Agri-Business Management Institute, NAU, Navsari, Gujarat, India
[*]Corresponding author E-mail: apchaudhary@nau.in
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ABSTRACT

The present study was conducted with objectives to create variability in the F_2 materials of SCS1061× GJHV510 cross of cotton through North Carolina Design-I, II and III. Total 80 crosses were developed in the *kharif* season of year 2022 and evaluated in Randomized Block Design with 2 replications during *kharif* season of year 2023 at Agricultural Research Station, Navsari Agricultural University (NAU), Achhalia. The data were recorded for seven characters *i.e.* plant height (cm), number of monopodia and sympodia branches/plant, days to 50% flowering, number of bolls/plant, seed yield/plant and lint yield/plant. The results revealed that there was huge variation was observed in developed materials for most of all the traits and materials developed through NCD-III showed more variability compared to other NCDs. The genetic divergence studies using Mahalanobis D^2 method distributed the 80 crosses of cotton into 12 different clusters. Cluster-I accommodated maximum (25) crosses while cluster-IX, X, XI and XII accommodated single diverse crosses. Cluster-X and XII showed maximum inter-cluster distance and materials from these cluster on the basis of lint yield, number of bolls/plant and plant height can be exploited in future breeding programs to develop better performing varieties/hybrids and also for breeding of advanced lines of cotton.

Keywords: Genetic divergence, Mahalanobis D^2, North Carolina Design, Cotton, Variability.

Introduction

The current study was carried out in cotton because it is one of the most important commercial crops cultivated in India and accounts for around 24% of the total global cotton production. It plays a major role in sustaining the livelihood of an estimated 6 million cotton farmers and 40-50 million people engaged in related activity such as cotton processing & trade. The Indian textile industry consumes a diverse range of fibres and yarns and the ratio of use of cotton to non-cotton fibres in India is around 60:40 whereas it is 30:70 in the rest of the world. Cotton crop provides the basic raw material (cotton fibre) to cotton textile industry and also contributes to edible oil. (Anonymous, 2024).

The North Carolina designs I, II and III were developed by Comstock and Robinson (1948, 1952) for estimation of two most important genetic parameters, additive genetic variance and dominance genetic variance. This mating design have two major aspects, first one deals with the development of experimental material by crossing of parents and second one is the field arrangement and evaluation of material generated by mating design. In this design, F_2 or any advanced generation maintained by random mating, produced from a cross between two pure-lines is taken as base population. In NCD-I and II, plants are randomly selected from base population to be used as male and female and mated in certain ways to produce progenies. Whereas, in NCD-III plants selected

randomly as male from base population were mated with both the parents as female to develop materials. The genetic divergence study through Mahalanobis D square method helps in understand the diversity in the developed materials and according to similarity, they were grouped together and it will be helpful in future breeding program.

Materials and Methods

Experimental location

This experiment was carried out into two parts viz. (i) Development of experimental materials and (ii) Evaluation of developed materials. The seeds of F_2 generation and parents of SCS1061× GJHV510 cross of cotton were obtained from the Main Cotton Research Station, Navsari Agricultural University (NAU), Surat. The crossing program was carried out in *kharif* season of year 2022 at Agricultural Research Station, NAU, Achhalia, Gujarat.

Development of experimental materials

Four plants were selected randomly as a male and each male was mated to four different randomly selected plants as female. Thus, 16 crosses per set were obtained in NCD-I. For NCD-II, four plants were selected randomly as a male and four plants as female by randomly selection. Thus, 16 crosses per set were obtained. In NCD-III, four plants were selected randomly as a male and crossed with both the parents as a female. Thus, 8 crosses per set were obtained. Thus, total 80 crosses were developed for evaluation purpose.

Evaluation of developed materials and characters under study

The evaluation of developed materials was carried out in *kharif* season of year 2023 in Randomized Block Design with two replications at Agricultural Research Station, NAU, Achhalia, Gujarat. Total ten plants of each entry were grown at a spacing of 120 cm × 45 cm and randomly five plants were selected to record observations. Data on plant height (cm), number of monopodia and sympodia branches/plant, days to 50% flowering, number of bolls/plants, seed yield/plant and lint yield/plant were recorded.

Statistical Analysis

Data were subjected to mean performance and variability parameters *i.e.* range, heritability (broad sense), genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) followed by genetic divergence using the Mahalanobis D^2 statistic with the crosses grouped on the basis of minimum generalized distance as described by Mohammadi and Prasanna (2003) using Toucher's method (Rao, 1952). The inter and intra-cluster distance among different clusters and the contribution of each character to total genetic divergence as the number of times that character appeared first in ranking was calculated according to Singh and Chaudhary (1979). The variability analysis was carried out by 'Variability' package of R-studio and Mahalanobis D^2 analysis was performed on 'TNAUSTAT-Statistical package' portal.

Results and Discussion

The overall mean, range, broad sense heritability, genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for different traits of cotton under study for the crosses developed through North Carolina Design-I, II and III were depicted in Table 1. The mean performance of crosses of different NCDs revealed that out of seven characters, crosses of NCD-I were found better in 3 characters (Plant height, number of sympodia branches/plant and seed yield/plant), NCD-II in 2 characters (Number of monopodia branches/plant and days to 50% flowering) and NCD-III also in 2 characters i.e. Number of bolls/plant and lint yield/plant.

The plant height varied from 104.8 to 159.6 in different NC designs. The maximum plant height was observed in crosses of NCD-I (135.21 cm). Highest heritability was observed in crosses of NCD-III whereas, GCV and PCV were observed higher in crosses of NCD-II. Number of monopodia branches/plant was observed minimum in NCD-II (1.70) and maximum heritability (88.81%), GCV (35.86%) and PCV (38.05%) also observed in crosses of NCD-II. The higher number of sympodia branches/plant were observed in NCD-I (32.51) whereas, highest heritability (95.02%) was observed for crosses of NCD-III and maximum GCV (17.31%) and PCV (17.88%) were recorded for NCD-II. The days to 50% flowering was observed almost similar for all the three NCDs and early flowering was noted in NCD-II (79.80 days). Crosses of NCD-III showed maximum heritability (68.62%) and maximum GCV (4.16%) and PCV (5.22%) were recorded in crosses of NCD-I. The maximum number of bolls/plants were recorded in case of NCD-III (43.05 bolls/plant) whereas, highest heritability (93.89%), GCV (19.48%) and PCV (20.11%) were observed in case of NCD-II. The higher seed yield/plant was recorded for NCD-I (65.0 g). The lint yield/plant was observed maximum in NCD-III with 52.3 g. Crosses of NCD-III showed highest heritability for seed yield and lint yield *i.e.* 95.30 per cent and 91.09 per cent, respectively. Overall

results suggested that materials developed through NCD-III showed more variability compare to NCD-I and II. The figure 1 showed the variability in the developed crosses for each trait. The maximum variation was observed for no. of monopodia branches/plant followed by lint yield/plant and seed yield/plant. There was less amount of variation was observed for days to 50% flowering.

Table 1: Mean and variability parameters of crosses developed by NCD-I, II and III for different traits of cotton

Characters	Parameters	NCD-I (32 crosses)	NCD-II (32 crosses)	NCD-III (16 crosses)
Plant height (cm)	**Mean**	**135.21**	131.8	132.04
	Range	106.1-159.6	104.8-150.8	117.8-151.5
	Heritability $_{(b)}$ (%)	73.19	85.85	**96.42**
	GCV (%)	7.65	**8.38**	7.43
	PCV (%)	8.95	**9.05**	7.57
Number of monopodia branches/plant	**Mean**	2.24	**1.70**	1.82
	Range	1.2-3.1	0.6-3.1	0.9-3.0
	Heritability $_{(b)}$ (%)	57.96	**88.81**	82.79
	GCV (%)	20.11	**35.86**	29.50
	PCV (%)	26.41	**38.05**	32.42
Number of sympodia branches/plant	**Mean**	**32.51**	30.30	30.88
	Range	24.1-40.7	20.4-40.0	22.4-39.3
	Heritability $_{(b)}$ (%)	33.34	93.78	**95.02**
	GCV (%)	9.77	**17.31**	13.76
	PCV (%)	16.93	**17.88**	14.12
Days to 50% flowering	**Mean**	80.02	**79.80**	79.88
	Range	73.0-86.5	75.5-84.0	74.5-84.0
	Heritability $_{(b)}$ (%)	63.58	59.52	**68.62**
	GCV (%)	**4.16**	2.57	3.24
	PCV (%)	**5.22**	3.33	3.91
Number of bolls/plant	**Mean**	42.43	39.80	**43.05**
	Range	33.8-53.4	26.3-57.6	31.2-56.1
	Heritability $_{(b)}$ (%)	46.61	**93.89**	89.99
	GCV (%)	8.76	**19.48**	14.16
	PCV (%)	12.83	**20.11**	14.93
Seed yield/plant (g)	**Mean**	**65.0**	59.0	59.4
	Range	34.0-84.0	35.6-83.2	43.0-83.7
	Heritability $_{(b)}$ (%)	53.43	56.37	**95.30**
	GCV (%)	16.76	15.94	**17.94**
	PCV (%)	**22.93**	21.23	18.38
Lint yield/plant (g)	**Mean**	42.0	38.4	**52.3**
	Range	23.0-60.8	25.6-49.5	36.8-73.7
	Heritability $_{(b)}$ (%)	68.76	44.49	**91.09**
	GCV (%)	**20.24**	12.95	19.60
	PCV (%)	**24.41**	19.41	20.54

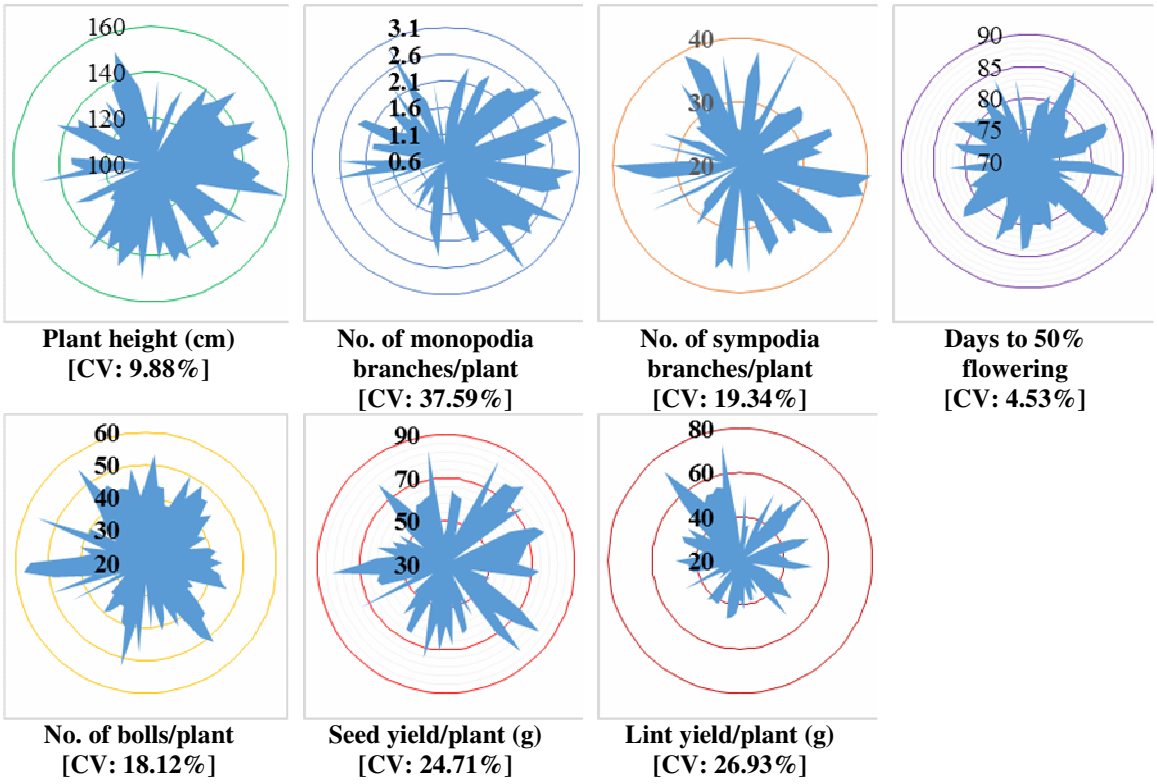

Fig. 1: Scatterness of crosses for different traits of cotton

The results of genetic divergence study using Mahalanobis D^2 analysis by Torcher method were presented in Table 2. Total 80 crosses were grouped into 12 clusters. Among the 12 different clusters, cluster-I was the biggest cluster accommodated 28 crosses followed by cluster-II with 10 crosses, cluster-III with 9 crosses, Cluster-IV and V with 8 crosses, Cluster-VI and VII with 5 crosses and cluster-VIII with 3 crosses, while remaining clusters accommodated only single diverse cross.

Table 2: Mahalanobis D^2 analysis of different crosses of cotton

Cluster No.	No. of crosses	Crosses in the cluster
I	28	M2F1(N1S2), M2F2(N2S1), M4F1(N2S1), M4F2(N2S2), M1F1(N2S2), M2F2(N3S1), M4F3(N2S1), M4F3(N1S1), M3F1(N1S1), M4F2(N2S1), M1F2(N2S2), M1F2(N1S2), M3F4(N2S1), M4F4(N2S1), M2F4(N2S1), M2F2(N1S1), M3F2(N1S1), M1F4(N1S2), M2F4(N1S1), M3F3(N2S2), M4F2(N1S1), M4F4(N1S2), M3F2(N2S1), M1F3(N1S2), M2F1(N1S1), M2F3(N2S1), M1F4(N2S2), M3F4(N1S1)
II	10	M3F2(N1S1), M2F3(N2S2), M1F1(N2S1), M3F3(N1S1), M3F1(N1S2), M3F3(N2S1), M2F1(N2S1), M2F1(N3S1), M1F4(N1S2), M4F4(N1S1)
III	9	M2F2(N2S2), M3F1(N2S1), M2F1(N2S1), M3F2(N2S2), M1F3(N2S2), M3F1(N3S1), M1F4(N2S1), M2F4(N2S2), M1F1(N3S1)
IV	8	M1F3(N1S1), M1F3(N2S1), M4F4(N2S2), M3F1(N2S2), M4F3(N2S2), M3F2(N3S1), M3F2(N2S2), M1F2(N2S1)
V	8	M2F3(N1S2), M4F2(N1S2), M2F2(N1S2), M4F1(N1S2), M4F3(N1S2), M2F2(N3S2), M1F1(N1S2), M3F4(N1S2)
VI	5	M4F2(N3S2), M1F2(N3S2), M1F1(N1S1), M1F2(N1S1), M3F2(N3S2)
VII	5	M4F1(N3S1), M3F1(N3S2), M4F2(N3S1), M2F1(N3S2), M4F1(N3S2)
VIII	3	M1F2(N3S1), M4F1(N2S2), M1F1(N3S2)
IX	1	M3F4(N2S2)
X	1	M2F4(N1S2)
XI	1	M3F3(N1S2)
XII	1	M2F3(N1S1)

M: Male parent; F: Female parent; N1: NCD-I; N2: NCD-II; N3: NCD-III; S1: Set-I and S2: Set-II

The intra and inter-cluster distance matrix was presented in Table 3. The results revealed that the intra-cluster distance was ranged from 0 (cluster IX, X, XI and XII) to 25.87 (cluster-VII). The maximum inter-cluster distance was recorded 163.61 between cluster-X and XII followed by 108.57 between cluster-I and XII, 107.36 between cluster-III and XII. The results also revealed that for further hybridization, the crosses should be made between materials of cluster-X and XII as well as between cluster-I and XII and cluster-III and XII for desired variation.

Table 3: Intra and Inter-cluster distance (D^2) matrix

Cluster No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	22.98	30.21	36.58	43.23	42.05	41.39	58.04	56.23	49.85	46.31	64.69	**108.57**
II		21.97	44.69	34.65	27.37	49.65	42.99	43.61	52.61	42.35	34.55	76.36
III			19.48	34.25	53.21	52.75	77.26	95.37	83.89	65.28	54.82	**107.36**
IV				17.76	50.58	41.82	60.44	60.43	50.97	74.69	32.63	52.04
V					19.69	80.33	52.40	65.09	69.58	49.85	46.19	74.53
VI						25.38	51.79	43.78	54.65	83.26	71.83	105.23
VII							25.87	35.31	84.20	88.02	51.93	85.45
VIII								20.44	47.88	78.75	69.87	83.34
IX									0.0	101.25	104.39	59.93
X										0.0	68.83	**163.61**
XI											0.0	70.91
XII												0.0

The centre points of the 12 cluster were depicted in Table 4. The results revealed that maximum (159.60 cm) plant height was recorded for crosses of cluster-X and minimum (106.10 cm) was recorded for cluster-XII. Number of monopodia branches/plant were recorded higher (3.10) in cluster-XI and lower (1.22) for cluster-VI. The maximum (39.90) number of sympodia branches/plant were observed for cluster-X while minimum (25.24) for cluster-III. Early (75.50 days) 50% flowering was observed in crosses of cluster-XI while, late (86.00 days) in cluster-XII. The maximum (57.60) number of bolls/plants were recorded for cluster-IX and minimum (30.84) for cluster-III. Seed yield/plant was recorded maximum (84.00 g) for cluster-XII while, minimum (41.60 g) for cluster-X and higher (62.54 g) lint yield was observed for cluster-VII and lower (25.30 g) in cluster-X. Hybridization between crosses of cluster-X and XII could be improve plant height, number of bolls/plants, days to 50% flowering, seed yield and lint yield due to highly diverse materials. The contribution of particular characters in total genetic divergence was presented in Table 4 and Figure 2. Among the different traits, lint yield showed maximum contribution (21.29 %) in total genetic divergence with 673-time first ranking followed by number of bolls/plant (20.35 %) with 643-time first ranking and plant height (19.84 %) with 627-time first ranking.

Table 4: Centre points of different clusters

Cluster No.	No. of crosses in cluster	Plant height (cm)	No. of monopodia branches/plant	No. of sympodia branches/plant	Days to 50% flowering	No. of bolls/ plant	Seed yield/ plant (g)	Lint yield/ plant (g)
I	28	138.62	1.75	29.65	79.88	41.40	61.78	40.48
II	10	136.74	2.52	33.71	79.45	43.13	65.53	43.53
III	9	123.48	1.26	25.24	80.44	30.84	47.88	34.19
IV	8	116.26	1.93	30.48	79.00	40.90	56.20	36.99
V	8	140.58	2.59	36.80	83.94	40.34	71.30	47.51
VI	5	126.96	1.22	28.60	76.10	45.50	54.84	44.20
VII	5	135.26	2.08	34.40	79.40	44.28	69.56	**62.54**
VIII	3	137.67	2.43	36.27	78.67	55.70	64.27	52.70
IX	1	129.50	1.90	36.40	82.50	**57.60**	83.20	43.50
X	1	**159.60**	2.80	**39.90**	76.50	43.50	41.60	25.30
XI	1	121.50	**3.10**	31.30	**75.50**	36.30	57.00	42.00
XII	1	106.10	2.40	39.80	86.00	49.90	**84.00**	54.10
First ranking		627	471	247	378	643	121	673
Contribution in divergence (%)		19.84	14.91	7.81	11.96	20.35	3.83	21.29

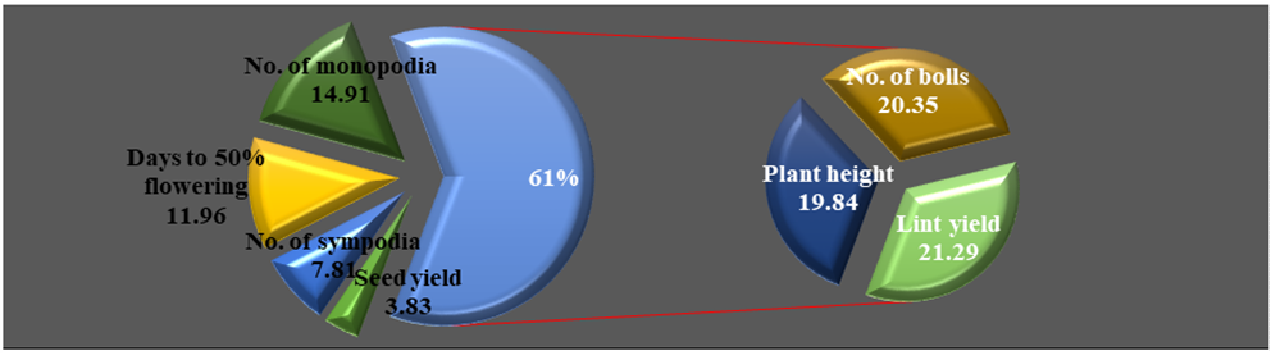

Fig. 2: Percentage contribution of characters of cotton in total genetic divergence

Conclusion

The present study revealed that there was huge variation was created through North Carolina Designs and among these three different NCDs, materials developed through NCD-III created more variability compared to NCD-I and II. Genetic divergence study revealed that Cluster-X and XII showed maximum inter-cluster distance and materials from these cluster on the basis of lint yield, number of bolls/plant and plant height can be exploited in further hybridization programs to develop better performing varieties/hybrids and also for breeding of advanced lines of cotton.

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